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BIOEMTECH

MOVING FORWARD TO PERSONALIZED PEDIATRIC DOSIMETRY ON COMPUTED TOMOGRAPHY APPLICATIONS

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INTRODUCTION

Continuing improvements in Computed Tomography (CT) technology, have dramatically increased the accuracy and usefulness of CT scanning and reduced the dose, which may partially account for increased use in medical diagnosis. However, the trend for increased numbers of procedures using this imaging modality may increase the overall doses.

Radiation sensitivity in pediatric population is much higher compared to adults, due to the long life expectation and the rapid cell replication.

The dose in each organ during CT scans can be obtained using Monte Carlo (MC) simulations and computational phantoms. GATE is a Monte Carlo simulation toolkit based on the precise modeling of the physical processes of the Geant4 code. It is dedicated for Nuclear Imaging applications and Radiotherapy with large flexibility in using voxelized phantoms and complex geometries with movement incorporation. GATE is extensively validated, although realistic simulations are highly demanding in computational resources.

PURPOSE

Our goal is:

- The creation of a software, freely available, for the dose calculation on specific organs for pediatric individuals undergoing **chest, abdomen/pelvis** and **head** computed tomography (CT) examinations.
- The **assessment** of the impact of different organ masses on the absorbed doses in tissue/organ level, using several models with variations in anatomical features.
- The estimation of organ effective doses for patients of different age, gender, and examination procedure.

METHODS

- ✓ **GATE** Monte Carlo simulation toolkit was used for modeling multislice CT scanner [1].
- ✓ **Spektr Software** was used for the generation of the X-ray energy spectra for a certain kVp setting [2].
- ✓ Validation of the CT Scanner Model was done with single axial scans **with standard head CTDI phantoms.**
- ✓ Six pediatric computational models in the 5 – 14 y age range were used to simulate realistic CT Protocols.
- ✓ International Commission on Radiological Protection Publication 103 was used [3].
- ✓ Helical chest, abdomen/pelvis and head protocols were simulated [4].
  - Relative errors were smaller than 2% with 10^8 particles
  - The simulations were carried out in the National HPC facility - ARIS (https://hpc.grnet.gr).
  - EMLivermore physics list of the Geant4 physics was selected.

chest & abdomen	normalized-to-CTDIvol absorbed doses (mGy/mGy) correlated with patient model weight
	absolute doses (mGy) correlated with effective diameter for the organs inside the scan range using linear regression analysis
head	normalized-to-CTDIvol absorbed doses (mGy/mGy) were correlated with specific head organ masses.
all protocols	absolute absorbed doses (mGy/100mAs)
	effective doses (mSv/100mAs)
	absorbed doses normalized to CTDIvol and 100 mAs (mGy/100mAs/mGy)
	variations in organ absorbed dose across all the patients were quantified by the coefficient of variation (standard deviation *100%/mean)

Table1. *Content of calculated database*

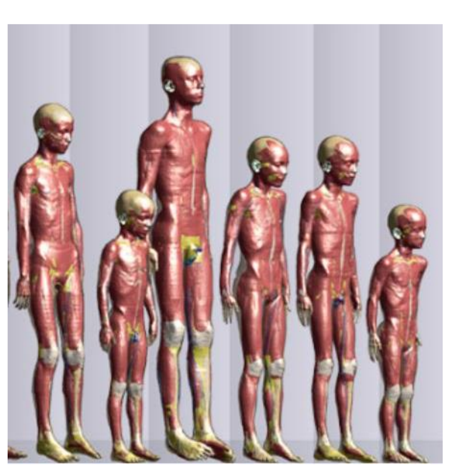

Figure1. *Pediatric Population from ITIS Foundation*

RESULTS

Energy (kVp)	Measured CTDI100 in air (mGy mAs^{-1})	Simulated CTDI100 in air (mGy particle^{-1})	Normalization factor (particle mAs^{-1})
120	3.65 x 10^{-1}	1.23 x 10^{-12}	2.96 x 10^{11}

Table2. *Measured and simulated CTDI100 in air at isocenter and derived normalization factor*

Position for head phantom	Ion chamber CTDIw (mGy)	Simulated CTDIw (mGy)	Difference %
CTDIw	47.86	53.39	10.92

Table3. *Comparison of CTDIw between simulated and clinical data*

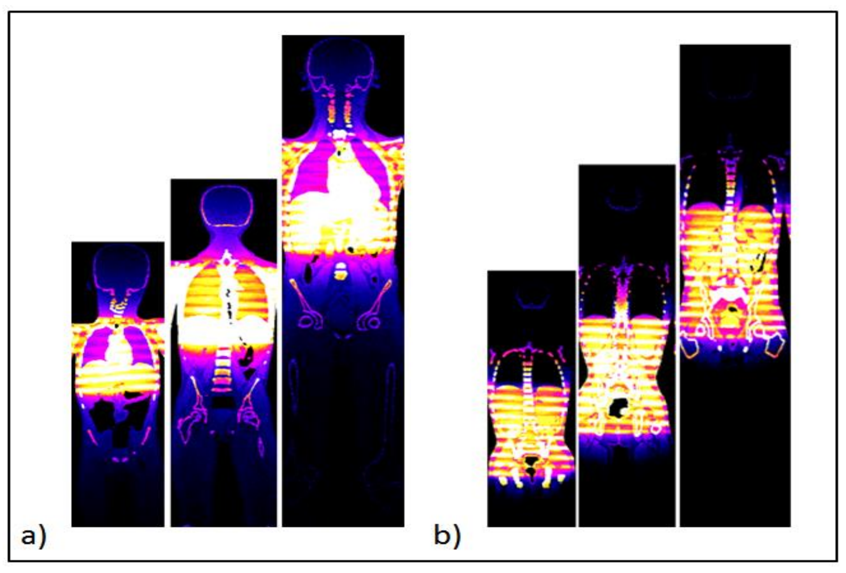

Figure2. *Helical dose maps from GATE: a) from chest CT scan (three males) and b) from abdomen CT scan (three females)*

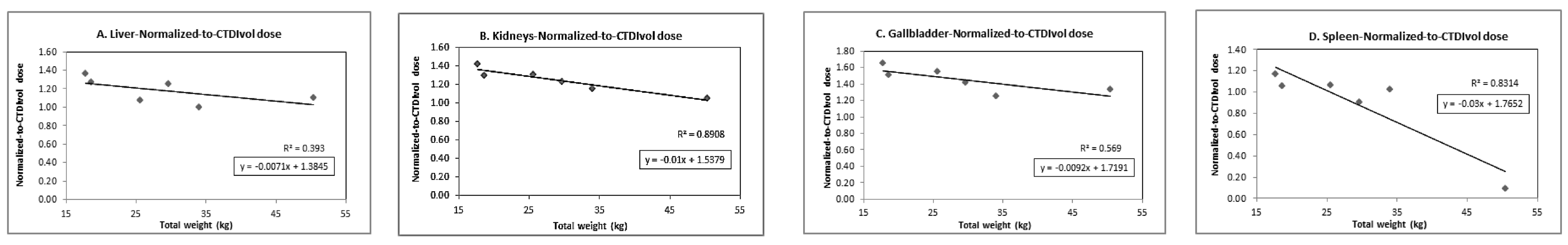

Figure3. *Normalized-to-CTDIvol absorbed doses (mGy/mGy) from the abdomen scan correlated with patient model weight using linear regression analysis for organs inside the scan range*

CONCLUSIONS

- ✓ The verification of the CT scanner was completed with high accuracy comparing experimental and simulated results.
- ✓ Absorbed doses in specific organs were calculated for three commonly used protocols.
- ✓ Variations up to 39%, 10% and 47% were noticed in the pediatric population for organs full inside the chest, abdomen/pelvis and head, respectively.
- ✓ The relationship of the dose was dependent on the location and size of the organ. For large organs within the image coverage, the exponential relationships were strong (R^2 = 0.36 for lungs and 0.14 for heart for chest protocol and bigger than 0.4 for abdomen/pelvis protocols).

Future step is to create a software tool, by which every patient could be matched to the best anatomical model of this database according to the characteristics of its internal organs, resulting to more accurate organ dose calculation.

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